BLISTER RUST CONTROL ABSTRACT

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P.L. Rusden, Agent, Plant Disease Control

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Abstract

Key spore dispersal

I. Introduction

Dispersal of passively air-borne particles, such as spores, results in a scatter around the point of liberation. The process is influenced by factors, so unpredictable at first sight that the resulting dispersion pattern might appear to defy analysis. Knowledge of the pattern is fundamental for the understanding and control of the dispersal process itself. This discussion will be based mainly on dry fungus spores in the role of plant pathogens.

The practice of isolating clean plants from sources of disease depends upon the fact that the contamination suffered generally decreases as one gets farther away from its source. The problem is to find whether any general relation exists between infection gradients. The problem is statistical. The destination of a single spore in an eddy of wind is insentable; for the average distribution of vast numbers of spores over a uniform area and for a period of time there is hope of rational treatment.

This survey first discusses the nature and magnitude of factors which control the scattering of air plankton. The literature is then examined to see whether the observed distributions of plant pathogens follow any recognizable patterns. Finally theapplication of the subject is discussed with special reference to the study and prevention of air-borne diseases of field crops.

II. The Factors Controlling Dispersal

The first stage in dispersal of fungus spores is their liberation from the structures in which they were formed. After liberation the spore is affected by gravity, wind, currents and electro-static forces. Consider first those forces acting on a single particle and then discuss the work relevant to groups of spores.

(1) The fate of an individual spore. Open air is never still. Even in a closed room are air currents affecting single spores. The rate at which spores fall in still air has been studied as a factor in distant dispersal.

For a very short period after discharge, a spore undergoes positive acceleration due to gravity (about one spore diameter) soon balanced by air resistance

and continuing to fall thereafter at constant terminal velocity which may even decrease if dessication reduces the mass of the spore. (Stokes Law for the velocity of fall of a smooth sphere in a viscous fluid is discussed at some length.) Vertical effect of gravity results in terminal velocity of fall (of single spore) of the order of 1 cm.sec.
(The necessity for modifying Stokes Law for non-spherical spores is discussed.)

(2) Minor forces acting on spores. Small electric charges probably negligible except within about a millimetre of another body. Temperature gradient. Light repulsion (photophoresis).

(3) Wind. Exerts a horizontal force. Wind speeds are commonly 300 times and usually at least 100 times as great as the rate of fall of spores under gravity. Hence, wind velocity is a major factor in controlling spore dispersal and may also play a part in the number of spores liberated by a plant.

(4) Spore dispersal as the resultant of horizontal and vertical forces. Such estimates are based on highly artificial conditions. There is some evidence that size of spore and the velocity of fall have little effect on the dispersal distance. The behavior of an individual spore is unpredictable with our present knowledge.

(5) The fate of a group of spores. The wind is characteristically turbulent with many small-scale eddies whose periods are of the order of 1 to 5 sec. Turbulence may be mechanical (friction between wind and ground) or thermal (convection currents). In clear weather is at a maximum soon after midday, while on a clear night thermal turbulence may die away completely if cooling of the ground by radiation leads to an inversion of temperature gradient(an increase in temperature with height instead of the usual decrease) in which there is no tendency for lower layers of air to ascent.

In turbulent air a puff of spores is continually being diluted as it is carried along, diffusing the spores in all directions and diminishing the density of the spore cloud. (Watch the effect of eddies on smoke from a chimney.) The effect if eddies is, therefore, much greater than theeffect of gravity.

(6) The spore cloud regarded as a suspension. Spore diameters approximate the sizes of droplets forming clouds or fog. The small speed of their fall and the stirring effect of atmpspheric turbulence make it tempting to regard the spore cloud as a suspension.

Like most other suspensions, the spore cloud will tend both to precipitate under gravity and to be stirred up by diffusion. The concentrations of spores at different heights in the atmosphere will be the result of the ineraction of these two forces. (Trapping and counting of spores at various heights above the earth is discussed)

...It seems appropriate to consider the spore cloud as a suspension in air. At heights of about 1000 m. and upwards the distribution agrees well with that expected from known values of terminal velocity and turbulence. Nearer ground

level, however, the suspension tends to become more uniform owing to the intermittent stirring of the lower layers by strong mechanical and diurnal thermal turbulence. Thus, over small areas micro-organisms are distributed at random in the air. Vertical dispersal depends upon turbulence in air (as in water for aquatic plankton).

(7) Spore deposition. One of themajor problems solved by those land plants that rely on air movement for the dispersal of spores is that of getting the spores away from the surface where they are formed, across the boundary layer of still or non-turbulent flowing air, and into the general circulation of the atmosphere. Once out of the calm layer of air close to the earth's surface, the spores can be freely transported by wind, and the spore cloud is diluted by eddies as it travels. Speed of fall probably plays only a small part in this stage of the dispersal process. But...when a spore is carried down by an eddy into the still surface air, the effect of gravity would predominate and electrostatic forces might be expected to play a part.

The fact that deposition (was found to be) smaller by night than by day is... due to lower turbulence (at night).

Rain has a marked effect and must set a limit to the process of dispersal by periodically washing the spore load out of the air. In many species of plants spores are not liberated during rains.

The factors domination the actual process of dispersal reduce to two; wind transport and eddy diffusion.

(8) Eddy diffusion. Literature is discussed and formula given.

Expressions for the density in a cloud(of spores) emitted from various types of sources are discussed.

(a) Instantaneous point source. Such as a puff or smoke emitted at an instant of time.

(b) Continuous point source. Such as a factory chimney emitting Q g. per sec.

(c) Continuous linesource at right angles to the direction of the wind. Emitting Q g. per sec. per cm. and assuming the line to be of infinite length.

## III. Horizontal Dispersion of Spores.

(Stepanov's and other experiments discussed)

## IV. Plant Disease Gradients

When disease data are given as the number or percentage of plants attached irrespective of whether the plant has one or many lesions,...the percentage will have to be suitably transformed before the formula for deposition can be applied.

Stakman stresses the need for experiments with 'marked' spores, easily identifiable and of known origin, in order to facilitate the development of the principles of airobiology.

The basidiospores of rusts...are known to be relatively short-lived when dry, but there seems to be no evidence that the death of spores in transit would decrease the number of successful infections over the distances of tens or hundreds of metres discussed in the paper. In a wind as slow as 0.5 m. sec. the sporidia of CRONARTIUM RIBICOLA would take only about 10 min. to travel the 900 feet regarded as the normal limit for infection of pines by this fungus. From data on the viability of its sporidia by Spaulding and Rathbun-Gravatt (1926) the absence of disease on plants at 900 feet seems more likely to be due to the great dilution of the cloud, making infection very improbable.

(1) Gradients from a point source. Blister rust (CRONARTIUM RIBICOLA (sic) is perennial in the stems of five-needle pines. On this host it produces aecidiospores which are capable of infecting only the leaves of the currant (RIBES) sp.). On the currant are produced uredospores capable of infecting other currants, and also teleutospores which on germination produce the sporidia (basidiospores) which are able to infect only pine needles. Spaulding (1920) noted a regularity about the infection on PINUS STROBUS observed by Prof. Pennington in the Adirondacks: 'In general, it may be said that under given conditions the number of infections in pine varies directly with the amount of RIBES leaf surface, and inversely as the square of the distance from RIBES.' Blister rust gradients were studied experimentally on PINUS MONTICOLA in British Columbia by Buchanan and Kinney (1938). Blocks of uninfected pine, 22.5 acres in area, were cleared of all currant bushes except for a group at the centre of the plots. These currants were inoculated to serve as a source of infection. RIBES was also removed from various zones around the plots. The infections on the pines resulting from spores produced by diseased currants were sometimes distributed evenly in all directions, but when the plots were on slopes the lesions tended to be more numerous down the slopes. Some of Buchanan and Kinney's tables show marked gradients, but as data are expressed in units of 'trees' of very diverse size they are not suitable for our purpose. From one of their graphs, however, can be read the pooled results of all their experiments in terms of cankers per million leaves...When plotted, the gradient shows a general agreement with the expected distribution, but also illustrates one or two points of discrepancy. The first point plotted on the graph is entered at 5 ft., which is the mean of the first zone measured from the plot centre, but as this central zone differs from all other zones in being partly occupied by the RIBES source instead of pine trees, it is not surprising that the number of cankers recorded should be lower than the theoretical value. The second point of interest is that beyond about 60 ft. the number of lesions becomes practically constant, suggesting that in some of the plots which contribute to the data a contamination on a low level may have been coming in from the outside. A similar effect from contamination was observed (elsewhere) for smoke pollution around (a city).

(Several other examples cited and discussed)

(2) Gradients from a line source.
(Discussion of the differences in spore dispersal from line sources (rows of plants or narrow blocks of plants)

V. Discussion

In the theory developed here, the dilution of the suspended spore cloud by eddies is regarded as the major factor controlling the deposition gradient, and in this respect the theory differs from the usual treatment by relegating the fall of spores and speed of wind to therole of second-order corrections. Horizontal and vertical dispersion are part of the same diffusion process, and the ultimate vertical gradient depends upon turbulence and rate of fall... observed gradients of undoubted wind-dispersed spores are compatible with recent theories of eddy diffusion in the atmosphere, and that data on spores dispersed from a point source are in very close agreement with it. ...
As a practical deduction...more reliance can be placed on the effect of spatial separation in protecting clean crops from contamination, but more attention should be paid to eliminating sources of infection within the crop itself. In a comparatively little known paper, Fracker (1936) has studied the influence of the distribution of sources of CRONARTIUM RIBICOLA within stands of PINUS STROBUS, and has obtained a measure of the effect of non-uniform distribution of RIBES in relation to the distribution of PINUS. It was shown that ecological factors causing aggregation of the RIBES resulted in fewer infected trees than would be expected from the same amount of RIBES uniformly scattered.

Blister Rust Control Significance

An appreciation of the mechanics of spore dispersal and deposition is essential to any consideration of the spread of white pine blister rust. Anyone seriously considering the problem of blister rust spread should study the original of P.H. Gregory's paper since this abstract has omitted all of his mathematics and has concentrated on the portions of the text considered most pertiment to blister rust control personnel.